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CLIMATE VARIABILITY AND EL NINO

This article has been contributed by the Bureau of Meteorology.

INTRODUCTION

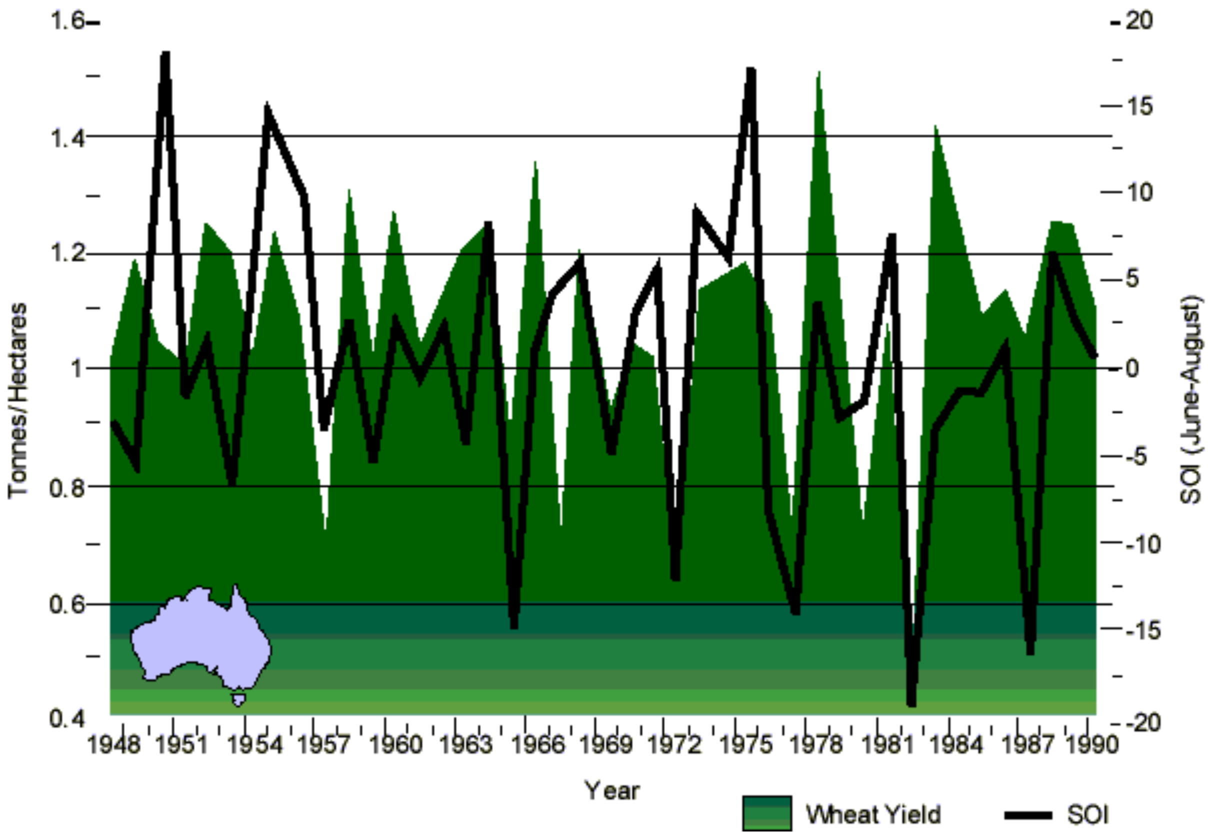
Generations of Australian school children have learned a poet's phrase describing their country as 'a land of droughts and flooding rains'. Today's scientists talk in terms of the continent's large climate variability from season to season, and from year to year.

The impact of climate variability on Australia was highlighted by events during the 1990s. In 1990-91 the wet season produced abundant rains, yet it failed almost completely the following year as drought set in across Queensland and New South Wales. Many people in southeast Australia will long remember the floods of spring 1992 and spring 1993, and the cool summers which followed. Dry conditions returned during the second half of 1994 and during the strong El Nino event of 1997.

What causes these fluctuations? They are connected with the climate phenomenon called the Southern Oscillation, a major air pressure shift between the Asian and east Pacific regions whose best-known extremes are El Nino events. The Southern Oscillation (strength and direction) is measured by a simple index, the Southern Oscillation Index (SOI), defined later. Rural productivity, especially in Queensland and New South Wales, is linked to the behaviour of the Southern Oscillation. Graph S1.1 shows how Australia's wheat yield (trend over time removed) has fluctuated with variations in the Southern Oscillation. Negative phases in the oscillation (drier periods) tend to have been linked with reduced wheat crops, and vice versa.

Tourism is also vulnerable to large swings in seasonal climate. Because climate variability can affect the Australian economy, it is important to understand the physical mechanisms controlling this dramatic feature of Australia's climate.

S1.1 AUSTRALIAN WHEAT YIELDS VERSUS SOI INDEX



Why 'El Nino'

El Nino translates from Spanish as 'the boy-child'. Peruvian anchovy fishermen traditionally used the term - a reference to the Christ child - to describe the appearance, around Christmas, of a warm ocean current off the South American coast, adjacent to Ecuador and extending into Peruvian waters (map S1.2). El Nino affects traditional fisheries in Peru and Ecuador. In most years, colder nutrient-rich water from the deeper ocean is drawn to the surface near the coast (upwelling), producing abundant plankton, food source of the anchovy. However, when upwelling weakens in El Nino years, and warmer low-nutrient water spreads along the coast, the anchovy harvest plummets. It was ruined in the four or five most severe El Nino events this century.

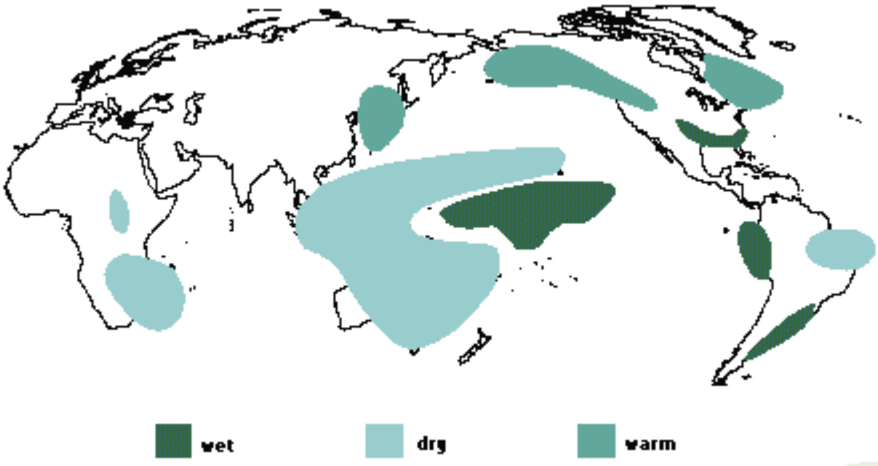
S1.2 HOME OF EL NINO

El Niño episodes bring a warm ocean current to the South American coast.

EL NINO'S GLONAL EFFECTS

The South American El Nino current is caused by large-scale interactions between the ocean and atmosphere. Today, the term El Nino refers to a sequence of changes in circulations across the Pacific Ocean and Indonesian archipelago when warming is particularly strong (on average every three to eight years). Characteristic changes in the atmosphere accompany those in the ocean, resulting in altered weather patterns across the globe (map S1.3).

S1.3 AREAS MOST CONSISTENTLY AFFECTED BY EL NINO



The Pacific Ocean's circulation features

The Pacific Ocean is a huge mass of water which controls many climate features in its region. Its

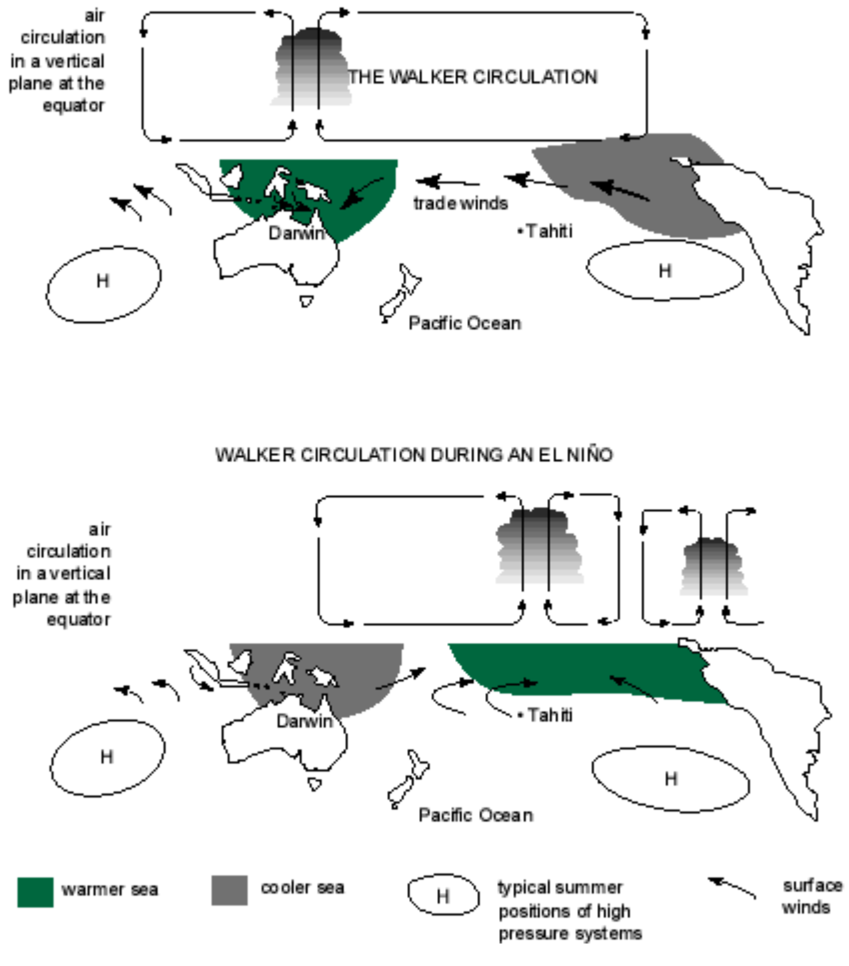
equatorial expanse, far larger than the Indian or Atlantic Oceans, is critical to the development of the Southern Oscillation and El Nino. In most years the Humboldt current brings relatively cold water northward along the west coast of South America, an effect increased by upwelling of cold water along the Peruvian coast. The cold water then flows westward along the equator and is heated by the tropical sun. These normal conditions make the western Pacific about 3 degrees C to 8 degrees C warmer than the eastern Pacific. However, in El Nino years the central or eastern Pacific may become as warm as the western Pacific.

The Walker circulation

The Walker circulation is named after Sir Gilbert Walker, a Director-General of British observatories in India who, early this century, identified a number of relationships between seasonal climate variations in Asia and the Pacific region.

The easterly Trade Winds are part of the low-level component of the Walker circulation. Typically, the Trades bring warm moist air towards the Indonesian region. Here, moving over normally very warm seas, moist air rises to high levels of the atmosphere. The air then travels eastward before sinking over the eastern Pacific Ocean. The rising air is associated with a region of low air pressure, towering cumulonimbus clouds and rain. High pressure and dry conditions accompany the sinking air. The wide variations in patterns and strength of the Walker circulation from year to year are shown maps S1.4.

S1.4 TYPICAL WALKER CIRCULATION PATTERN



The Southern Oscillation

'By the Southern Oscillation is implied the tendency of pressure at stations in the Pacific ... to

increase, while pressure in the region of the Indian Ocean ... decreases.'

- Sir Gilbert T. Walker, 1924

This definition remains valid. We now say that the Southern Oscillation occurs because of the large changes in the Walker circulation closely linked to the pattern of tropical Pacific sea temperatures.

The Southern Oscillation Index (SOI)

The Southern Oscillation Index (SOI) gives us a simple measure of the strength and phase of the Southern Oscillation, and indicates the status of the Walker circulation. The SOI is calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin.The 'typical' Walker circulation pattern shown in graph S1.4 has an SOI close to zero (Southern Oscillation close to the long-term average state). When this pattern is strong the SOI is strongly positive (Southern Oscillation at one extreme of its range). When the Walker circulation enters its El Nino phase, the SOI is strongly negative (Southern Oscillation at the other extreme of its range).

Positive values of the SOI are associated with stronger Pacific trade winds and warmer sea temperatures to the north of Australia. Together these give a high probability that eastern and northern Australia will be wetter than normal. During El Nino episodes, the Walker circulation weakens, seas around Australia cool, and slackened trade winds feed less moisture into the Australian/Asian region. There is then a high probability that eastern and northern Australia will be drier than normal.

CLIMATE CLUES TO EL NINO

Meteorologists watch for changes to the atmosphere and ocean circulation which help them detect an El Nino, or forecast its lifetime. Indicators are:

- the Walker circulation and trade winds weaken. During more intense El Nino episodes, westerly winds are observed over parts of the equatorial western and central Pacific;
- the area of warm water usually over the western tropical Pacific cools and the warmest water is displaced eastward to the central Pacific;
- the normally cold waters on the South American coast warm by 2oC to 8oC;
- the Southern Oscillation Index remains negative; and
- enhanced cloudiness develops over the central equatorial Pacific.

Map S1.5 shows some areas of drought since 1951 that have been related to an El Nino episode.

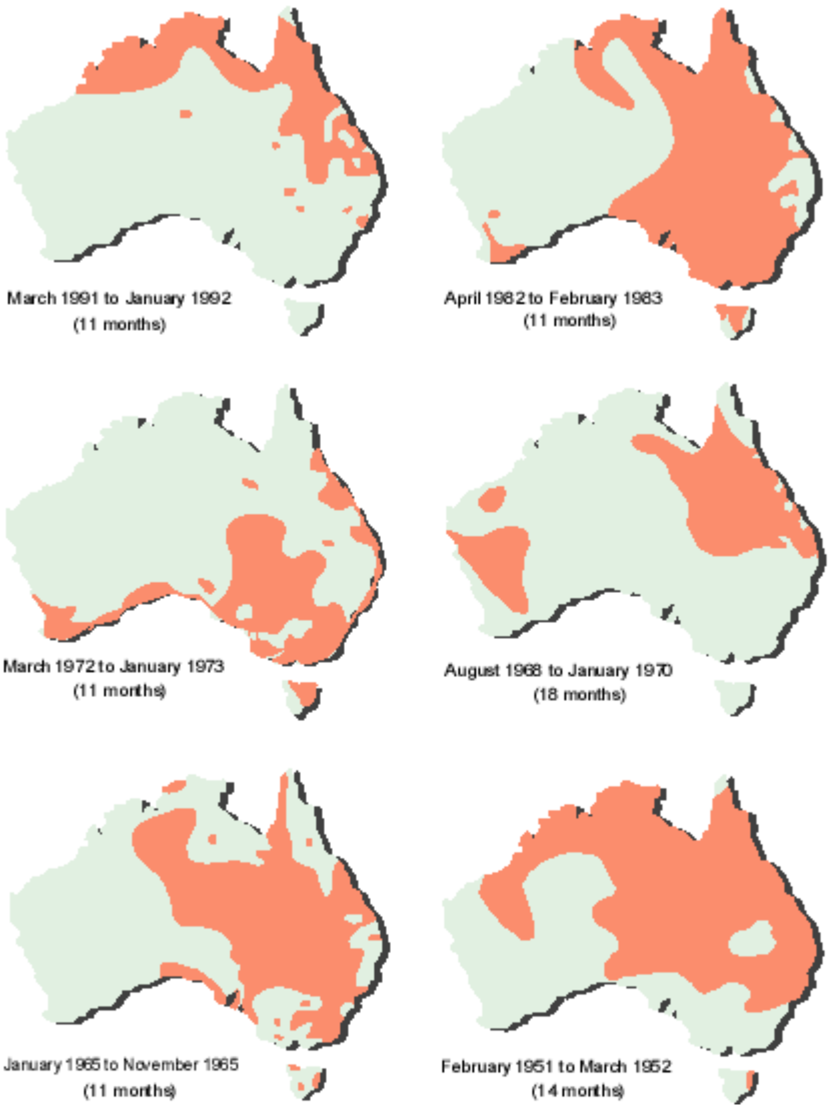
EL NINO'S OPPOSITE PHASE

When the Southern Oscillation Index sustains high positive values, the Walker circulation intensifies, and the eastern Pacific cools. These changes often bring widespread rain and flooding to Australia - this phase is sometimes called anti-El Nino (or La Nina). Australia's strongest recent examples were in 1973-74 (Brisbane's worst flooding this century in January 1974) and 1988-89 (vast areas of inland Australia had record rainfall in March 1989).

FORECASTING EL NINO

Scientists have made important advances in understanding El Nino/Southern Oscillation (ENSO) phenomena in recent decades. These led to the National Climate Centre's launch of the Seasonal Climate Outlook Service in 1989. The service offers medium-term (three months ahead) outlooks of rainfall. A new ocean model looks at ocean temperatures to six months ahead and beyond in an attempt to look to how long the El Nino conditions will last. Summary information is available on the Australian Bureau of Meteorology's Internet Web site (http://www.bom.gov.au/), on the pollfax facsimile service known as 'Weather by Fax', and through detailed information provided in a monthly publication available by subscription. Useful predictions of seasonal rainfall have the potential to contribute to the goals of sustainable development in the rural sector.

S1.5 EL NINO RELATED DROUGHT AREAS IN AUSTRALIA SINCE 1951



Changes in Australian rainfall have been strongly linked to El Nino Southern Oscillation patterns.

However, work continues to identify other climate shifts associated with ENSO events in order to help forecast these changes for Australia. Studies for Queensland and northern New South Wales have shown that the number of frosts is likely to increase during an El Nino event, with frosts occuring later in the year than normal, thereby putting new spring growth at risk.

Recent work in the Bureau's Research Centre has shown significant potential for seasonal temperature outlooks. Early results suggest that during an El Nino spring there is a slight tendency for an increase in the frequency of hot days as well as an overall increase in the average maximum temperature. A similar but more pronounced pattern is evident in summer.

The 1997 El Nino event

The signs of a developing El Nino event emerged during autumn 1997 when the Southern Oscillation Index (SOI) began a rapid decline. In early May the National Climate Centre issued advice that there was a strong chance of an El Nino event developing, as the SOI and other important indicators from the tropical Pacific pointed to further strengthening of the emerging pattern.

The majority of El Nino events in the historical record had their genesis in autumn and an approximate 12-month life cycle, including a decay phase beginning in either the summer or autumn of the following year. This tendency for events to be 'locked' to the seasonal cycle is fundamental to the science of climate prediction and enables a much higher level of predictability than would otherwise be the case.

The 1997 El Nino event followed the historical pattern of development in its timing, but was unusual in that it gained intensity much more rapidly than most previous events, particularly in terms of ocean temperature anomalies. Concurrent with the dramatic fall in SOI values was the development of a large body of anomalously warm water in the eastern equatorial Pacific, a classic sign of El Nino. By late July 1997, ocean temperatures in the far eastern equatorial Pacific were about 4 degrees C above normal, the strongest anomalies since the 1982-83 event, and unusually intense for this stage of an event. Even in a strong event, which this was, it would be more typical to see anomalies of this magnitude in late spring or summer.

Winter 1997 rainfall was below average for much of Australia. However timely falls in spring 1997 greatly improved harvest prospects. This was a blessing particularly to parts of Victoria which had experienced the driest 11 months on record up to the end of August 1997. It is important to note that each El Nino event is unique with respect to rainfall patterns and areas affected by dry conditions. Although 1997's El Nino event was classed as a 'strong' event, i.e. the climate indicators were a long way from normal, it does not necessarily follow that the stronger the event, the drier the conditions.

World attention focused on the 1997 El Nino event - improved communications since the 1982-83 event and the realities of a global on-line economy meant that information spread quickly and was readily accessible. The ENSO phenomenon had effects in various parts of the globe, including severe droughts and choking bushfires arising from dry conditions which affected South-east Asia and including nearby Papua New Guinea and Indonesia.

In the last decade, computer models have developed in their ability to predict ocean temperatures. However we need other methods to gain an idea of the kind of rainfall patterns Australia can expect during an El Nino event. Analysing the rainfall from previous El Nino events is the best guide to the likely evolution of rainfall patterns across the country beyond the prediction period of the Bureau's statistical Seasonal Outlook. A method of matching this event with similar years is to compare the SOI behaviour over the past nine months with a span of similar calendar months from the historical record. The closest matches are then chosen.

Applying this method of SOI comparison to the 1997 event, the eight years which most closely match the current event up to the end of July (called SOI analogues) are: 1972, 1982, 1991, 1977, 1946, 1965, 1994, and 1914, which are all El Nino years. Winter/spring rainfall maps for these years are available through the Bureau's Internet Web site.

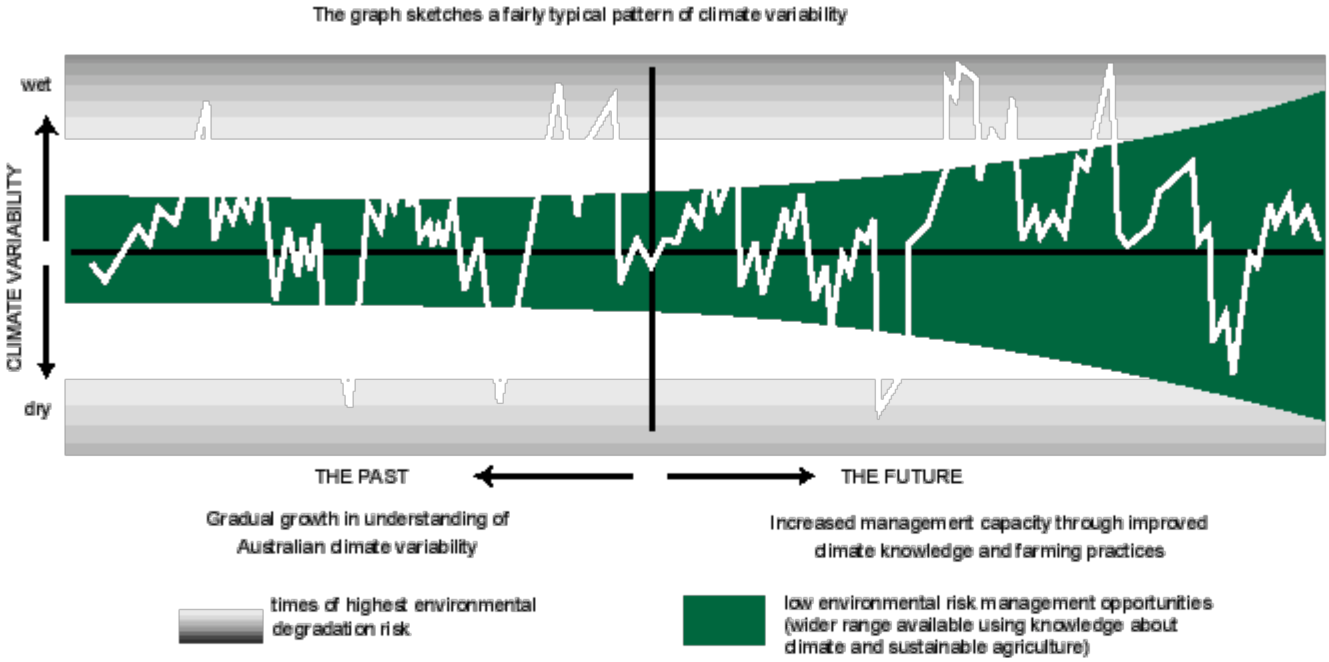
THE FUTURE

A large proportion of Australia's natural environment is farmed, harvested or managed by farmers. Many renewable resources, from topsoil to wildlife, are broadly under rural sector management. Rural communities need the best climate advice to help them protect and sustain national ecological resources in the face of climate extremes. Improved understanding of climate variability, and application of appropriate management techniques, will be crucial to achieving sustainable development goals.

Sustainable development requires improved management in all climate ranges, especially during climate extremes, which bring the greatest risk of environmental degradation. Graph 1.6 suggests how improved climate understanding and forecast skill may increase the range of low-risk conditions, and enhance our capacity to better manage high-risk periods.

El Nino is one of the significant climate indicators we know of that can warn us of shifts in weather patterns. Even so, our climate will continue to vary all by itself as it has done for centuries - we are unlikely to ever understand it fully and warn of all these occasions. However, El Nino is one indicator we can use to warn of dry times ahead.

S1.6 MANAGING FOR THE IMPACT OF CLIMATE ON AGRICULTURE



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